SPP Definition

PRTN #177

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I user behavior

The term "user" in this note refers not only to a person but also to a user level program or even to routines within an SPP implementation which perform user level functions in place of an explicit user program.

The user is assumed to be well-behaved in three ways. First, the user and SPP entity taken as a pair shall not permit unlimited retransmissions of a packet for which no acknowledgement is received. Rather, the connection shall eventually be terminated by the user, or by the SPP entity on behalf of the user.

Second, the user is signalled when a close is received and accepted from the remote end of the connection. When this signal is generated, all data through and including the packet containing the close has been either delivered to the user or buffered so that the user may obtain it at will. The user is expected to execute a "close" call after sending any final data he may wish to send, and a "terminate" call when both the "close" call and the reading of any data desired are completed.

Third, the user is informed when an illegal open has been received and the connection consequently aborted. The user is expected to issue a "terminate" call after this notification is made.

II matching received packets to connections

Certain criteria distinguish an SPP connection. When an SPP packet is received, the SPP entity applies some of these criteria to the packet to determine whether the packet matches any of its connections which are in a state capable of accepting the packet. For the purpose of matching a received packet to a connection, the criteria which identify connections are:

local ID
foreign ID

Each connection has, at any given instant, a class of values for each of these criteria. If the values in the corresponding fields of the received packet's header all fall within the acceptance classes of a given connection, then the packet is matched to and delivered to that connection. A received packet is delivered to at most one connection, which the SPP implementor shall enforce by defining the algorithm by which connections are scanned in any given SPP implementation, and by refusing user requests to create connections which, with the defined scan algorithm, would produce multiply defined matching situations. Received packets matching no connections are discarded.

The acceptance class of local ID for a given connection shall have one member.

The acceptance class of foreign ID for a given connection shall have one or more members when the connection is created. If it has more than one member, the class shall be reduced to one member when the first received packet is matched to this connection or when a user call "initiate transmit side" is serviced, whichever happens first.

III state diagram

Figure 1 presents the simplified SPP state diagram. It is simplified in three ways. First, "transitions" which do not result in a change of state are not indicated. All events which cause actions are listed in section IV, including those which do not cause a change of state.

Second, Figure 1 employs a graphical ellipsis for the three transitions to state LLA and the eight transitions to state AAA.

Third, a large number of transitions to states CCC and NNN, caused by the user executing a "terminate" call, have been omitted. These are implied in Figure 2, in which each state inside the dotted line has a transition to state CCC or NNN resulting from user execution of a "terminate" call. These transitions and attendant actions are listed fully in section IV.

The events which cause SPP actions and/or state transitions are:

- user calls:
  - create
  - initiate transmit side
  - send data
  - close
  - terminate
- user action:
  - read all data delivered
- reception from network:
  - open indication
  - data
  - close indication
  - acknowledgement
- timeouts:
  - expiration of T1
  - expiration of T2
  - expiration of T3

Some of these events cause actions dependent on the state. There are 28 distinct event and action packages, as listed in Table 1. In Figure 3 the state transitions are labeled with the (arbitrarily assigned) number of the event and action package associated with that transition. Thus, a transition labeled "11" is caused by a user executing a "create" call when space is available; no action is associated with the transition; and the new state is as indicated in Figure 3 and as listed in section IV.

The primordial state is PPP.

IV functional definition of states

Table 2 lists each state. Under each state, each event which causes an action and/or state transition is listed. Under each event, the action and/or transition which the given event causes in the given state is listed.

If a particular user call is listed under a given state, servicing that event implicitly includes providing a success return to the user. If a particular user call is not listed under a given state, user execution of that call is illegal and shall result in an error return to the user.

If a particular event other than a user call is not listed under a given state, occurrence of that event is ignored.

If no action is listed for a given state and event, no action is performed. If no state transition is listed for a given state and event, no state transition is performed.

V multiple function packets

A received packet matched to a connection may or may not contain open indication, may or may not contain data, and may or may not contain close indication. After being matched (and hence delivered) to a given connection, the packet will either be accepted by that connection or rejected. The acceptance decision is based upon the sequence number of the packet, the presence or absence of open indication, the state of the connection, and the left window edge (LWE) of the connection. The acceptance decision process is detailed in Table 2. If the packet is rejected, it may either be discarded without causing any action, or it may provoke transmission of an acknowledgement. This also is detailed in Table 2.

After SPP accepts a packet on a given connection, the packet is examined for open indication. If present, the actions appropriate to receiving an open in the current state are executed. Next, actions caused by the arrival of any packet in the current state are executed. The packet is then examined for close indication. If present, the actions appropriate to receiving a close in the current state are executed. Execution of each set of actions is accompanied by any appropriate state transition. During the servicing of the packet, however, at most one acknowledgement may be prepared. Similarly, LWE may not increase beyond its proper value even though the packet may be serviced by executing multiple sets of actions.

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VI acknowledgements

The left window edge (LWE) is the sequence number of the next packet desired on the connection. The last such value of LWE is still referred to as LWE while the connection still exists but no more packets are "desired," as in state CCC. The next sequence number to use on the transmit side is similarly preserved.

When an acknowledgement is prepared, the sequence number contained in the acknowledgement is LWE minus one (modulo 65536). An acknowledgement cumulatively acknowledges all packets on the connection prior to and including the one whose sequence number appears in the acknowledgement.

The receipt of an acknowledgement may provide more than one event. If an outstanding open is acknowledged, a state transition is made. Hence, "receipt of acknowledgement of open" is listed as a distinct event. If an outstanding close is acknowledged, a state transition is made. Hence, "receipt of acknowledgement of close" is listed as a distinct event. In any case, retransmission of any outstanding packets which the received acknowledgement acknowledges is ceased. Hence, "receipt of acknowledgement of packet" is listed as a distinct event.

The order in which events provided by receipt of an acknowledgement shall be serviced is:

receipt of acknowledgement of open
receipt of acknowledgement of packet
receipt of acknowledgement of close

VII multiple function user calls

If an SPP implementation provides a user call which specifies, "initiate transmit side and send this data," then the transmitted traffic may consist of either one dataless packet with open indication and one packet without open indication but bearing data, or one packet with both open indication and data.

If an SPP implementation provides a user call which specifies, "send this data and close," then the transmitted traffic may consist of either one packet bearing data without close indication and one dataless packet with close indication, or one packet with both data and close indication.

If an SPP implementation provides a user call which specifies, "initiate transmit side, send this data, and close," then the transmitted traffic may consist of one, two or three packets in analogy to the two cases above.

If an SPP implementation provides a user call which specifies, "create and initiate transmit side," then the actions and transition appropriate to servicing a user call "create" are executed, followed by execution of the actions and transition

appropriate to servicing a user call "initiate transmit side." If an SPP implementation provides only this combined form of user call, then a direct state transition shall be made without an explicit intermediate state.

Similarly, if an SPP implementation combines "create," "initiate transmit side" and "send this data," then the logical components are serviced in sequence. Such a user call additionally combined with "close" is serviced similarly.

VIII buffering data bound for user

The SPP entity may be implemented to buffer data which arrives before the LWE has reached the sequence number of the packet. In such an implementation, no action shall be taken as a result of the early acceptance of this packet. Specifically, an acknowledgement will not be sent at the time of early acceptance. Data in the packet will not be delivered to the user until all preceding data has been accepted and delivered to the user, unless the SPP implementation provides an option for delivery of unsequenced data and the user has selected that option. In any case, a close indication in the packet accepted early shall not be acted upon until all preceding packets have been accepted and serviced.

Once received data has been acknowledged it is discarded by the SPP entity only if the user executes a "terminate" call. Otherwise, such data remains available for the user to read indefinitely. The act of the user reading received data removes the data from the SPP entity.

IX option to suppress automatic return open

Receipt of an open indication in states LLL or LLLT may or may not automatically cause an open indication to be returned on the transmit side of the connection. If not, the user must eventually execute an "initiate transmit side" call (or a "terminate" call).

The SPP implementor shall provide one or the other of these modes of operation, or a facility by which the user specifies in the "create" call which mode is desired.

If a return open is transmitted automatically, the following states and transitions involving them do not exist:

LL3T, LL3, LL4T, LL4.

If a return open is not transmitted automatically, the following state transitions do not exist:

LLLT to 113T

LLL to 113T.

X timeouts

Timeout T1 is begun whenever any of the following transitions occur:

enter state 444T
enter state AAA
enter state CCC other than from state RRRT.

Timeout T1 proceeds as long as the state remains within the set of states

{444T,RRRT,CCC,LLLT,11LT,12LT,41LT,42LT,44LT,AAA}.

After the state leaves the above set, T1 is no longer relevant and is aborted, disabled or otherwise ignored, as appropriate to the given programming environment. When T1 is begun it is initialized to PAL as defined below.

Timeout T2 is begun whenever an open indication is accepted and opens the receive side of the connection, that is, whenever a transition labeled 21a, 21b, 22a or 22b on the state diagram is made. It proceeds as long as the state remains within the set of states

{LL3T,113T,123T,413T,423T,443T,
LL4T,114T,124T,414T,424T,PP3T,PP4T}.

After the state leaves the above set, T2 is no longer relevant and is aborted or ignored as appropriate. When T2 is begun it is initialized to PAL as defined below.

Timeout T3 is begun whenever SPP is reinitialized, such as power on or restart after a crash. It proceeds as long as the state remains within the set of states

{PPP,PPL,PP3T,PP3,PP4T,PP4,PPA}.

After the state leaves the above set, T3 is no longer relevant and is aborted or ignored as appropriate. When T3 is begun it is initialized to PAL minus the shortest duration which may have elapsed since the SPP entity concerned was last operating. If an SPP implementation is such that the initial value of T3 can never exceed zero, the primordial state is NNN and the following states and transitions involving them do not exist:

PPP,PPL,PP3T,PP3,PP4T,PP4,PPA.

Packets which have not been (end to end) acknowledged are retransmitted. Such retransmission of outstanding packets shall occur at some roughly regular interval. This retransmission interval shall be easily modified in SPP implementations where it has a fixed value. Until such time as experience provides better guidelines, the initial value in fixed value SPP implementations shall lie between one half second and one second. The interval may be dynamically modified by software during execution.

The time interval PAL (packet activity lifetime) is the total of the maximum value of each of the following:

1) the time between SPP attempting to halt transmissions and retransmissions of a given packet, and that packet no longer being possibly given to the attached PR
2) the time between a packet being given to the attached PR and no copies of the packet remaining in any PRs
3) the time between delivery of a packet to its (ultimate) destination PR's attached device and that device handing its attached PR any required acknowledgement
4) the time for all copies of the acknowledgement to die out of the network of PRs
5) the time for any acknowledgement delivered by the attached PR to be seen and acted upon.

Until such time as experience provides better guidelines, the value of PAL used in SPP implementations shall exceed ten seconds.

XI packet header

word	bits	field
0	15-12	hop count
	11-8	header length (in words)
	7-0	packet length (in words)
1		source ID
	15-3	device
	2-0	use
2		destination ID
	15-3	device
	2-0	use
3		sequence number
4	15-13	type 0 = search (ROP) 1 = label 2 = executable by PR (control) 3 = information 4 = response to control 5, 6, 7 = undefined
	12	end-to-end acknowledgement, ETE ACK 0 = original packet 1 = acknowledgement
	11	direction, DIR 0 = outbound from station 1 = inbound to station
	10-8	function 0 = non-SPP traffic 1, 2, 3 = undefined 4 = normal SPP information packet 5 = open SPP connection 6 = close SPP connection 7 = open, then close SPP connection
	7	alternate routing has occurred (ART)
	6	end-to-end acknowledgement is requested (ARQ)
	5	alternate routing is in progress (PRN internal use)
	4	undefined
	3-0	hierarchy level
5		undefined
6,7,8,9		routing labels, one to four words

XII caveat

SPP design demands that applications requiring the ultimate in reliability also implement TCP. See PRTN 165 for discussion.

XIII epilogue

We tend to accept a design only when it is presented in familiar terms; simultaneously assimilating both a new product design and a new conceptual format seems to tax our patience and comprehension. For this reason, SPP is defined as a finite state machine even though it has the ungainly state diagram presented in section III.

The SPP heterostate diagram, to be presented in a future document, is a much more tractable presentation of SPP. We expect the heterostate document will contain discussion and motivation for SPP design. Such a didactic document does not satisfy the needs of the Packet Radio Working Group for an SPP definition, however, as previous experience has shown. The present document has been intentionally trimmed of ambiguous and expositional discussion.

A balance exists between an obsequious and an oblivious relation to historical development of SPP. A definition in a vacuum is a vacuous definition; nevertheless, this document refers to prior documents only for an understanding of the network and its operation, and then only implicitly. All previous SPP literature should be considered background material.

The proper boundary between SPP definition and free implementation is a matter of taste. Strictly speaking, it makes the most sense to define only as much as necessary to ensure that two SPP entities abiding by the definition will communicate with each other. Everything else would be left for the implementor to define. On the other hand, a feel for how the SPP entity behaves internally, and for how it appears to the user, are important aids to understanding. In this document the line is drawn approximately at the point which divides those operations which are necessary for an SPP entity to function from those which are not.

One example of implementation dependent operations omitted from this document is signalling the user "closed." The SPP entity must know when the user no longer needs the connection. That is, when the user will neither transmit nor attempt to receive any more data or control information. This has been provided in the user call "terminate." Receipt of this call permits the SPP entity to reclaim resources allocated to the connection. Similarly, in an implementation where the SPP and user entities are distinct processes, the user needs to know when the SPP entity is finished. SPP implementations in such environments should provide such an indication to the user. This might take the form of a "closed" signal upon transition to any of the states PPP, NNN, CCC.

In the final analysis we must depend on the strict interpretation:

> Any SPP implementation, in particular any user interface design, is acceptable if and only if its behavior, as seen by an SPP entity as defined herein and with which it is communicating, is the same as that of the latter communicating with a twin.

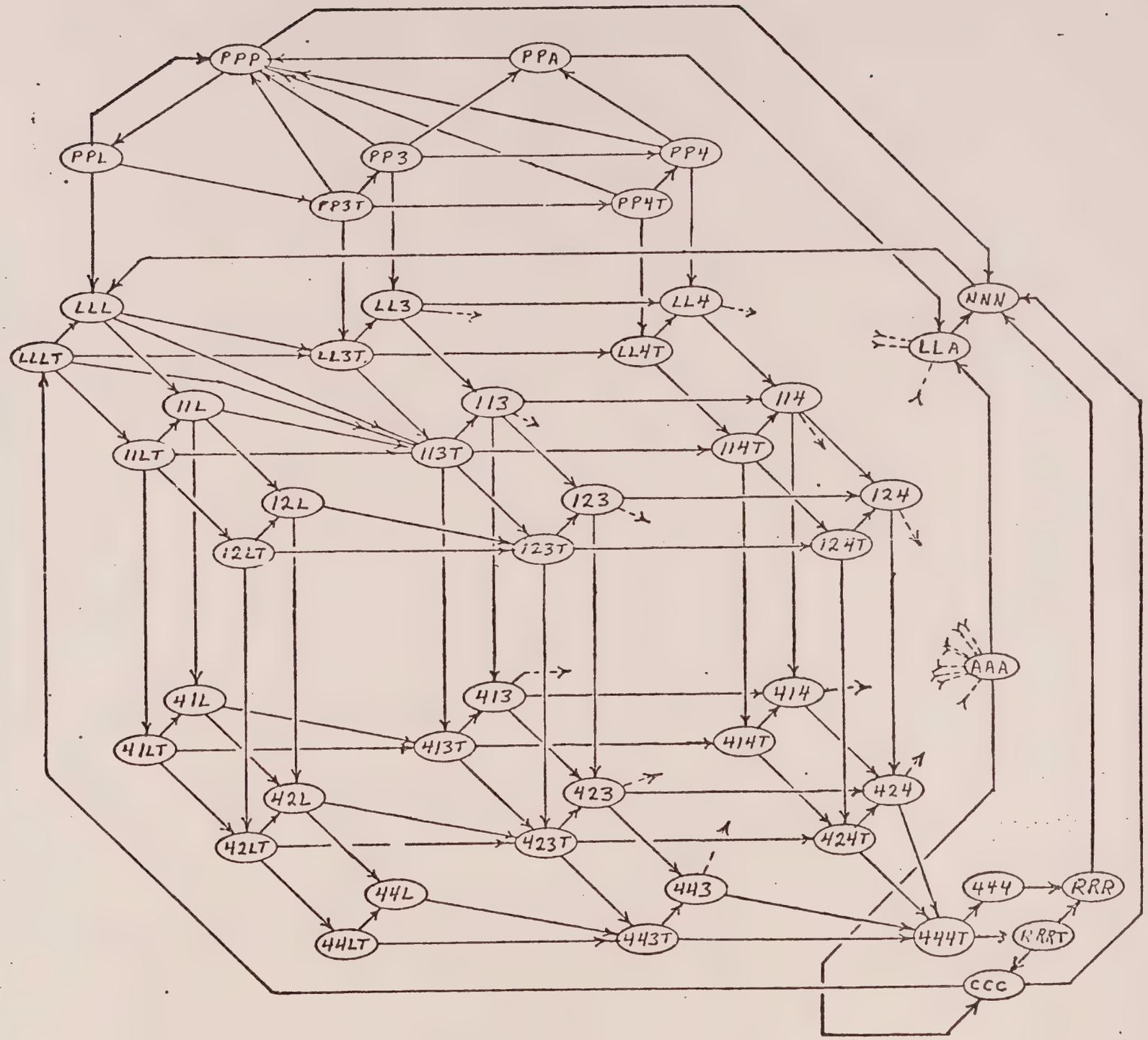
PPP
PPA
PPL
PP3
PP4
PP3T
PP4T
LLL
LL3
LL4
NNN
LLLT
LL3T
LL4T
LLA
11L
113
114
11LT
113T
114T
12L
123
124
12LT
123T
124T
AAA
41L
413
414
41LT
413T
414T
42L
423
424
42LT
423T
424T
44L
443
444
RRR
44LT
443T
444T
RRRT
CCC

FIGURE 1.

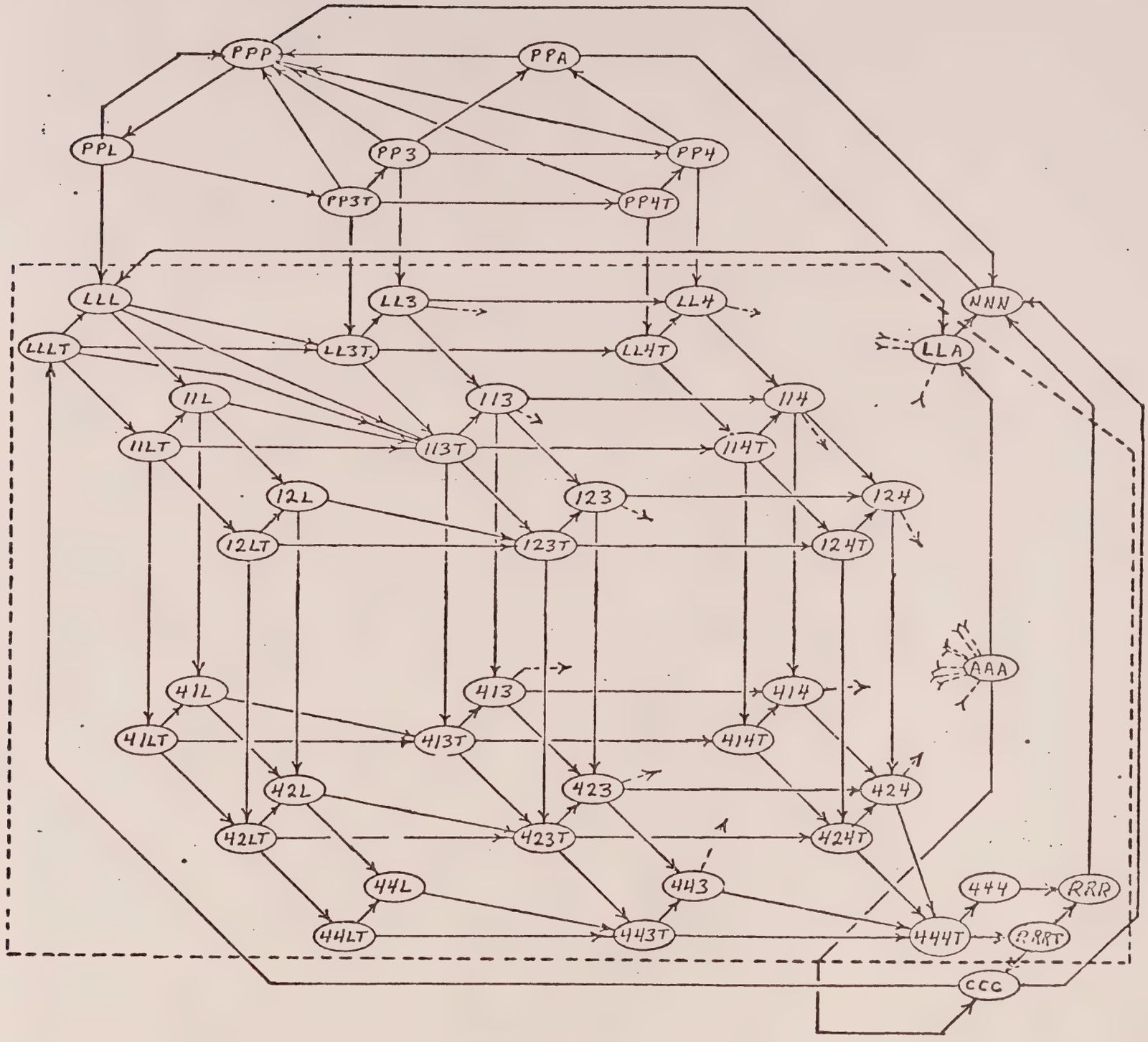
PPP
PPA
PPL
PP3
PP4
PP3T
PP4T
LLL
LL3
LL4
NNN
LLLT
LL3T
LL4T
LLA
11L
113
114
11LT
113T
114T
12L
123
124
12LT
123T
124T
AAA
41L
413
414
41LT
413T
414T
42L
423
424
42LT
423T
424T
44L
443
444
RRR
44LT
443T
444T
RRRT
CCC

FIGURE 2.

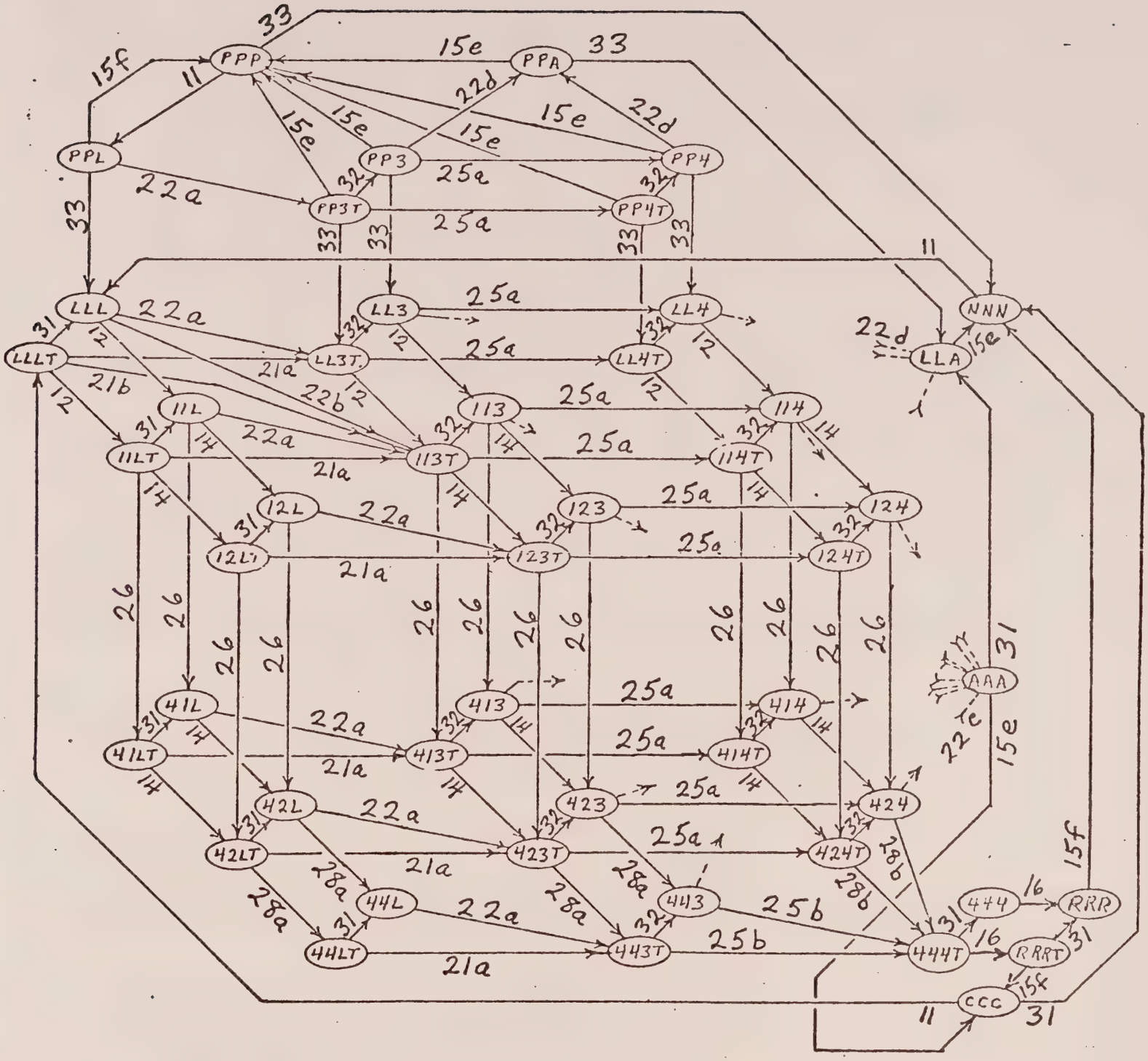
PPP
PPA
PPL
PP3
PP4
PP3T
PP4T
LLL
LL3
LL4
NNN
LLLT
LL3T
LL4T
LLA
11L
113
114
11LT
113T
114T
12L
123
124
12LT
123T
124T
AAA
41L
413
414
41LT
413T
414T
42L
423
424
42LT
423T
424T
44L
443
444
RRR
44LT
443T
444T
RRRT
CCC

FIGURE 3.

22b event: receipt of open indication
  action: prepare a packet with open indication and place it
          on transmit and retransmit queues
        set left window edge
        set timer T2

22c event: receipt of open indication
  action: delete all packets from transmit queue, and
          from retransmit queue if possible
        signal user "aborted"
        make transition, then reprocess packet as if not yet
          matched to a connection
        set timer T1

22d event: receipt of open indication
  action: signal user "aborted"
        make transition, then reprocess packet as if not yet
          matched to a connection

23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue

24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
          number = left window edge

25a event: receipt of close indication
  action: signal user "received and accepted close" in such
          a way that signal arrives after all data

25b event: receipt of close indication
  action: signal user "received and accepted close" in such
          a way that signal arrives after all data
        set timer T1

26 event: receipt of acknowledgement of open

27 event: receipt of acknowledgement of packet
  action: delete any outstanding, acknowledged packets from transmit
          queue, and from retransmit queue if possible

28a event: receipt of acknowledgement of close

28b event: receipt of acknowledgement of close
        set timer T1

31 event: expiration of timeout T1

32 event: expiration of timeout T2

33 event: expiration of timeout T3

```
PPP
11 event: user executes "create" call and space is available
  transition: PPL
33 event: expiration of timeout T3
  transition: NNN

PPL
15f event: user executes "terminate" call
  transition: PPP
22a event: receipt of open indication
  action: set left window edge
        set timer T2
  transition: PP3T
33 event: expiration of timeout T3
  transition: LLL

PPA
15e event: user executes "terminate" call
  action: delete all unread data destined for user
  transition: PPP
33 event: expiration of timeout T3
  transition: LLA

PP3T
15e event: user executes "terminate" call
  action: delete all unread data destined for user
  transition: PPP
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
                number = left window edge
25a event: receipt of close indication
  action: signal user "received and accepted close" in such
                a way that signal arrives after all data
  transition: PP4T
32 event: expiration of timeout T2
  transition: PP3
33 event: expiration of timeout T3
  transition: LL3T
```

PP3
15e event: user executes "terminate" call for user
  action: delete all unread data destined for user
  transition: PPP
22d event: receipt of open indication
  action: signal user "aborted"
        make transition, then reprocess packet as if not yet
              matched to a connection
  transition: PPA
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
              number = left window edge
25a event: receipt of close indication
  action: signal user "received and accepted close" in such
              a way that signal arrives after all data
  transition: PP4
33 event: expiration of timeout T3
  transition: LL3

PP4T
15e event: user executes "terminate" call for user
  action: delete all unread data destined for user
  transition: PPP
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
32 event: expiration of timeout T2
  transition: PP4
33 event: expiration of timeout T3
  transition: LL4T

PP4
15e event: user executes "terminate" call for user
  action: delete all unread data destined for user
  transition: PPP
22d event: receipt of open indication
  action: signal user "aborted"
        make transition, then reprocess packet as if not yet
              matched to a connection
  transition: PPA
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
33 event: expiration of timeout T3
  transition: LL4

continued.

```
AAA
15e event: user executes "terminate" call
  action: delete all unread data destined for user
  transition: CCC
31 event: expiration of timeout T1
  transition: LLA

LLA
15e event: user executes "terminate" call
  action: delete all unread data destined for user
  transition: NNN

NNN
11 event: user executes "create" call and space is available
  transition: LLL

LLLT
12 event: user executes "initiate transmit side" call
  action: prepare a packet with open indication and place it
                on transmit and retransmit queues
  transition: 11LT
15f event: user executes "terminate" call
  transition: NNN
21a event: receipt of open indication in packet whose sequence
                number = left window edge
  action: set timer T2
  transition: LL3T
21b event: receipt of open indication in packet whose sequence
                number = left window edge
  action: prepare a packet with open indication and place it
                on transmit and retransmit queues
        set timer T2
  transition: 113T
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
31 event: expiration of timeout T1
  transition: LLL

LLL
12 event: user executes "initiate transmit side" call
  action: prepare a packet with open indication and place it
                on transmit and retransmit queues
  transition: 11L
15f event: user executes "terminate" call
  transition: NNN
22a event: receipt of open indication
  action: set left window edge
        set timer T2
  transition: LL3T
22b event: receipt of open indication
  action: prepare a packet with open indication and place it
                on transmit and retransmit queues
        set left window edge
        set timer T2
  transition: 113T
```

LL3T
12 event: user executes "initiate transmit side" call
  action: prepare a packet with open indication and place it
          on transmit and retransmit queues
  transition: 113T
15e event: user executes "terminate" call
  action: delete all unread data destined for user
  transition: NNN
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
          number = left window edge
25a event: receipt of close indication
  action: signal user "received and accepted close" in such
          a way that signal arrives after all data
  transition: LL4T
32 event: expiration of timeout T2
  transition: LL3

LL3
12 event: user executes "initiate transmit side" call
  action: prepare a packet with open indication and place it
          on transmit and retransmit queues
  transition: 113
15e event: user executes "terminate" call
  action: delete all unread data destined for user
  transition: NNN
22d event: receipt of open indication
  action: signal user "aborted"
        make transition, then reprocess packet as if not yet
          matched to a connection
  transition: LLA
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
          number = left window edge
25a event: receipt of close indication
  action: signal user "received and accepted close" in such
          a way that signal arrives after all data
  transition: LL4

page 19 - Table 2 continued.

LL4T
12 event: user executes "initiate transmit side" call
  action: prepare a packet with open indication and place it
          on transmit and retransmit queues
  transition: 114T
15e event: user executes "terminate" call
  action: delete all unread data destined for user
  transition: NNN
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
32 event: expiration of timeout T2
  transition: LL4

LL4
12 event: user executes "initiate transmit side" call
  action: prepare a packet with open indication and place it
          on transmit and retransmit queues
  transition: 114
15e event: user executes "terminate" call
  action: delete all unread data destined for user
  transition: NNN
22d event: receipt of open indication
  action: signal user "aborted"
      make transition, then reprocess packet as if not yet
          matched to a connection
  transition: LLA
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue

11LT
13 event: user executes "send data" call
  action: prepare a packet containing data, and place it
          on transmit and retransmit queues
14 event: user executes "close" call
  action: prepare a packet with close indication and place it
          on transmit and retransmit queues
  transition: 12LT
15b event: user executes "terminate" call
  action: delete all packets from transmit queue, and
          from retransmit queue if possible
      set timer T1
  transition: CCC
21a event: receipt of open indication in packet whose sequence
          number = left window edge
  action: set timer T2
  transition: 113T
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
26 event: receipt of acknowledgement of open
  transition: 41LT
31 event: expiration of timeout T1
  transition: 11L

```
11L
13 event: user executes "send data" call
  action: prepare a packet containing data; and place it
                on transmit and retransmit queues
14 event: user executes "close" call
  action: prepare a packet with close indication and place it
                on transmit and retransmit queues
  transition: 12L
15b event: user executes "terminate" call
  action: delete all packets from transmit queue; and
                from retransmit queue if possible
        set timer T1
  transition: CCC
22a event: receipt of open indication
  action: set left window edge
        set timer T2
  transition: 113T
26 event: receipt of acknowledgement of open
  transition: 41L

113T
13 event: user executes "send data" call
  action: prepare a packet containing data, and place it
                on transmit and retransmit queues
14 event: user executes "close" call
  action: prepare a packet with close indication and place it
                on transmit and retransmit queues
  transition: 123T
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
                number = left window edge
25a event: receipt of close indication
  action: signal user "received and accepted close" in such
                a way that signal arrives after all data
  transition: 114T
26 event: receipt of acknowledgement of open
  transition: 413T
32 event: expiration of timeout T2
  transition: 113
```

```
113
13 event: user executes "send data" call
  action: prepare a packet containing data, and place it
                on transmit and retransmit queues
14 event: user executes "close" call
  action: prepare a packet with close indication and place it
                on transmit and retransmit queues
  transition: 123
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
22c event: receipt of open indication
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        signal user "aborted"
        make transition, then reprocess packet as if not yet
                matched to a connection
        set timer T1
  transition: AAA
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
                number = left window edge
25a event: receipt of close indication
  action: signal user "received and accepted close" in such
                a way that signal arrives after all data
  transition: 114
26 event: receipt of acknowledgement of open
  transition: 413

114T
13 event: user executes "send data" call
  action: prepare a packet containing data, and place it
                on transmit and retransmit queues
14 event: user executes "close" call
  action: prepare a packet with close indication and place it
                on transmit and retransmit queues
  transition: 124T
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
26 event: receipt of acknowledgement of open
  transition: 414T
32 event: expiration of timeout T2
  transition: 114
```

```
114
13 event: user executes "send data" call
  action: prepare a packet containing data, and place it
                on transmit and retransmit queues
14 event: user executes "close" call
  action: prepare a packet with close indication and place it
                on transmit and retransmit queues
  transition: 124
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
22c event: receipt of open indication
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        signal user "aborted"
        make transition, then reprocess packet as if not yet
                matched to a connection
        set timer T1
  transition: AAA
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
26 event: receipt of acknowledgement of open
  transition: 414

12LT
15b event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        set timer T1
  transition: CCC
21a event: receipt of open indication in packet whose sequence
                number = left window edge
  action: set timer T2
  transition: 123T
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
26 event: receipt of acknowledgement of open
  transition: 42LT
31 event: expiration of timeout T1
  transition: 12L

12L
15b event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        set timer T1
  transition: CCC
22a event: receipt of open indication
  action: set left window edge
        set timer T2
  transition: 123T
26 event: receipt of acknowledgement of open
  transition: 42L
```

```
123T
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
                number = left window edge
25a event: receipt of close indication
  action: signal user "received and accepted close" in such
                a way that signal arrives after all data
  transition: 124T
26 event: receipt of acknowledgement of open
  transition: 423T
32 event: expiration of timeout T2
  transition: 123

123
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
22c event: receipt of open indication
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        signal user "aborted"
        make transition, then reprocess packet as if not yet
                matched to a connection
        set timer T1
  transition: AAA
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
                number = left window edge
25a event: receipt of close indication
  action: signal user "received and accepted close" in such
                a way that signal arrives after all data
  transition: 124
26 event: receipt of acknowledgement of open
  transition: 423
```

```
124T
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
26 event: receipt of acknowledgement of open
  transition: 424T
32 event: expiration of timeout T2
  transition: 124

124
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
22c event: receipt of open indication
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        signal user "aborted"
        make transition, then reprocess packet as if not yet
                matched to a connection
        set timer T1
  transition: AAA
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
26 event: receipt of acknowledgement of open
  transition: 424

41LT
13 event: user executes "send data" call
  action: prepare a packet containing data, and place it
                on transmit and retransmit queues
14 event: user executes "close" call
  action: prepare a packet with close indication and place it
                on transmit and retransmit queues
  transition: 42LT
15b event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        set timer T1
  transition: CCC
21a event: receipt of open indication in packet whose sequence
                number = left window edge
  action: set timer T2
  transition: 413T
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
27 event: receipt of acknowledgement of packet
  action: delete any outstanding, acknowledged packets from transmit
                queue, and from retransmit queue if possible
31 event: expiration of timeout T1
  transition: 41L
```

41L
13 event: user executes "send data" call
  action: prepare a packet containing data, and place it
          on transmit and retransmit queues
14 event: user executes "close" call
  action: prepare a packet with close indication and place it
          on transmit and retransmit queues
  transition: 42L
15b event: user executes "terminate" call
  action: delete all packets from transmit queue, and
          from retransmit queue if possible
        set timer T1
  transition: CCC
22a event: receipt of open indication
  action: set left window edge
        set timer T2
  transition: 413T
27 event: receipt of acknowledgement of packet
  action: delete any outstanding, acknowledged packets from transmit
          queue, and from retransmit queue if possible

413T
13 event: user executes "send data" call
  action: prepare a packet containing data, and place it
          on transmit and retransmit queues
14 event: user executes "close" call
  action: prepare a packet with close indication and place it
          on transmit and retransmit queues
  transition: 423T
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
          from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
          number = left window edge
25a event: receipt of close indication
  action: signal user "received and accepted close" in such
          a way that signal arrives after all data
  transition: 414T
27 event: receipt of acknowledgement of packet
  action: delete any outstanding, acknowledged packets from transmit
          queue, and from retransmit queue if possible
32 event: expiration of timeout T2
  transition: 413

page 26 - Table 2 continued.

413
13 event: user executes "send data" call
action: prepare a packet containing data, and place it
on transmit and retransmit queues
14 event: user executes "close" call
action: prepare a packet with close indication and place it
on transmit and retransmit queues
transition: 423
15a event: user executes "terminate" call
action: delete all packets from transmit queue, and
from retransmit queue if possible
delete all unread data destined for user
set timer T1
transition: CCC
22c event: receipt of open indication
action: delete all packets from transmit queue, and
from retransmit queue if possible
signal user "aborted"
make transition, then reprocess packet as if not yet
matched to a connection
set timer T1
transition: AAA
23 event: receipt of packet whose sequence number < left window edge
action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
action: prepare acknowledgement and place it on transmit queue
deliver data, if any, to user
advance left window edge
service any buffered packet whose sequence
number = left window edge
25a event: receipt of close indication
action: signal user "received and accepted close" in such
a way that signal arrives after all data
transition: 414
27 event: receipt of acknowledgement of packet
action: delete any outstanding, acknowledged packets from transmit
queue, and from retransmit queue if possible

414T
13 event: user executes "send data" call
action: prepare a packet containing data, and place it
on transmit and retransmit queues
14 event: user executes "close" call
action: prepare a packet with close indication and place it
on transmit and retransmit queues
transition: 424T
15a event: user executes "terminate" call
action: delete all packets from transmit queue, and
from retransmit queue if possible
delete all unread data destined for user
set timer T1
transition: CCC
23 event: receipt of packet whose sequence number < left window edge
action: prepare acknowledgement and place it on transmit queue
27 event: receipt of acknowledgement of packet
action: delete any outstanding, acknowledged packets from transmit
queue, and from retransmit queue if possible
32 event: expiration of timeout T2
transition: 414

414
13 event: user executes "send data" call
  action: prepare a packet containing data, and place it
          on transmit and retransmit queues
14 event: user executes "close" call
  action: prepare a packet with close indication and place it
          on transmit and retransmit queues
  transition: 424
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
          from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
22c event: receipt of open indication
  action: delete all packets from transmit queue, and
          from retransmit queue if possible
        signal user "aborted"
        make transition, then reprocess packet as if not yet
          matched to a connection
        set timer T1
  transition: AAA
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
27 event: receipt of acknowledgement of packet
  action: delete any outstanding, acknowledged packets from transmit
          queue, and from retransmit queue if possible

42LT
15b event: user executes "terminate" call
  action: delete all packets from transmit queue, and
          from retransmit queue if possible
        set timer T1
  transition: CCC
21a event: receipt of open indication in packet whose sequence
          number = left window edge
  action: set timer T2
  transition: 423T
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
27 event: receipt of acknowledgement of packet
  action: delete any outstanding, acknowledged packets from transmit
          queue, and from retransmit queue if possible
28a event: receipt of acknowledgement of close
  transition: 44LT
31 event: expiration of timeout T1
  transition: 42L

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42L
15b event: user executes "terminate" call
  action: delete all packets from transmit queue, and
          from retransmit queue if possible
        set timer T1
  transition: CCC
22a event: receipt of open indication
  action: set left window edge
        set timer T2
  transition: 423T
27 event: receipt of acknowledgement of packet
  action: delete any outstanding, acknowledged packets from transmit
          queue, and from retransmit queue if possible
28a event: receipt of acknowledgement of close
  transition: 44L

423T
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
          from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
          number = left window edge
25a event: receipt of close indication
  action: signal user "received and accepted close" in such
          a way that signal arrives after all data
  transition: 424T
27 event: receipt of acknowledgement of packet
  action: delete any outstanding, acknowledged packets from transmit
          queue, and from retransmit queue if possible
28a event: receipt of acknowledgement of close
  transition: 443T
32 event: expiration of timeout T2
  transition: 423

page 29 - Table 2 continued.

```
423
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
22c event: receipt of open indication
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        signal user "aborted"
        make transition, then reprocess packet as if not yet
                matched to a connection
        set timer T1
  transition: AAA
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
                number = left window edge
25a event: receipt of close indication
  action: signal user "received and accepted close" in such
                a way that signal arrives after all data
  transition: 424
27 event: receipt of acknowledgement of packet
  action: delete any outstanding, acknowledged packets from transmit
                queue, and from retransmit queue if possible
28a event: receipt of acknowledgement of close
  transition: 443

424T
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
                from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
27 event: receipt of acknowledgement of packet
  action: delete any outstanding, acknowledged packets from transmit
                queue, and from retransmit queue if possible
28b event: receipt of acknowledgement of close
        set timer T1
  transition: 444T
32 event: expiration of timeout T2
  transition: 424
```

424
15a event: user executes "terminate" call
  action: delete all packets from transmit queue, and
          from retransmit queue if possible
        delete all unread data destined for user
        set timer T1
  transition: CCC
22c event: receipt of open indication
  action: delete all packets from transmit queue, and
          from retransmit queue if possible
        signal user "aborted"
        make transition, then reprocess packet as if not yet
          matched to a connection
        set timer T1
  transition: AAA
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
27 event: receipt of acknowledgement of packet
  action: delete any outstanding, acknowledged packets from transmit
          queue, and from retransmit queue if possible
28b event: receipt of acknowledgement of close
        set timer T1
  transition: 444T

44LT
15d event: user executes "terminate" call
  action: set timer T1
  transition: CCC
21a event: receipt of open indication in packet whose sequence
          number = left window edge
  action: set timer T2
  transition: 443T
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
31 event: expiration of timeout T1
  transition: 44L

44L
15d event: user executes "terminate" call
  action: set timer T1
  transition: CCC
22a event: receipt of open indication
  action: set left window edge
        set timer T2
  transition: 443T

page 31 - Table 2 continued.

```
443T
15c event: user executes "terminate" call
  action: delete all unread data destined for user
        set timer T1
  transition: CCC
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
                number = left window edge
25b event: receipt of close indication
  action: signal user "received and accepted close" in such
                a way that signal arrives after all data
        set timer T1
  transition: 444T
32 event: expiration of timeout T2
  transition: 443

443
15c event: user executes "terminate" call
  action: delete all unread data destined for user
        set timer T1
  transition: CCC
22d event: receipt of open indication
  action: signal user "aborted"
        make transition, then reprocess packet as if not yet
                matched to a connection
  transition: LLA
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
24 event: receipt of packet whose sequence number = left window edge
  action: prepare acknowledgement and place it on transmit queue
        deliver data, if any, to user
        advance left window edge
        service any buffered packet whose sequence
                number = left window edge
25b event: receipt of close indication
  action: signal user "received and accepted close" in such
                a way that signal arrives after all data
        set timer T1
  transition: 444T
```

444T
15f event: user executes "terminate" call
  transition: CCC
16 event: user reads all data delivered
  transition: RRRT
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
31 event: expiration of timeout T1
  transition: 444

444
15f event: user executes "terminate" call
  transition: NNN
16 event: user reads all data delivered
  transition: RRR

RRRT
15f event: user executes "terminate" call
  transition: CCC
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
31 event: expiration of timeout T1
  transition: RRR

RRR
15f event: user executes "terminate" call
  transition: NNN

CCC
11 event: user executes "create" call and space is available
  transition: LLLT
15f event: user executes "terminate" call
23 event: receipt of packet whose sequence number < left window edge
  action: prepare acknowledgement and place it on transmit queue
31 event: expiration of timeout T1
  transition: NNN

· page 33 - Table 2 concluded.

PPP-11/PPL
NNN-11/LLL
CCC-11/LLLT

LLLT-12/11LT
LLL-12/11L
LL3T-12/113T
LL3-12/113
LL4T-12/114T
LL4-12/114

11LT-13/NONE
11L-13/NONE
113T-13/NONE
113-13/NONE
114T-13/NONE
114-13/NONE
41LT-13/NONE
41L-13/NONE
413T-13/NONE
413-13/NONE
414T-13/NONE
414-13/NONE

11LT-14/12LT
11L-14/12L
113T-14/123T
113-14/123
114T-14/124T
114-14/124
41LT-14/42LT
41L-14/42L
413T-14/423T
413-14/423
414T-14/424T
414-14/424

113T-15a/CCC
113-15a/CCC
114T-15a/CCC
114-15a/CCC
123T-15a/CCC
123-15a/CCC
124T-15a/CCC
124-15a/CCC
413T-15a/CCC
413-15a/CCC
414T-15a/CCC
414-15a/CCC
423T-15a/CCC
423-15a/CCC
424T-15a/CCC
424-15a/CCC

11LT-15b/CCC
11L-15b/CCC
12LT-15b/CCC
12L-15b/CCC
41LT-15b/CCC
41L-15b/CCC
42LT-15b/CCC
42L-15b/CCC

443T-15c/CCC
443-15c/CCC

44LT-15d/CCC
44L-15d/CCC

PP3T-15e/PPP
PP3-15e/PPP
PP4T-15e/PPP
PP4-15e/PPP
PPA-15e/PPP
AAA-15e/CCC
LLA-15e/NNN
LL3T-15e/NNN
LL3-15e/NNN
LL4T-15e/NNN
LL4-15e/NNN

PPL-15f/PPP
LLLT-15f/NNN
LLL-15f/NNN
444T-15f/CCC
444-15f/NNN
RRRT-15f/CCC
RRR-15f/NNN
CCC-15f/NONE

444T-16/RRRT
444-16/RRR

LLLT-21a/LL3T
11LT-21a/113T
12LT-21a/123T
41LT-21a/413T
42LT-21a/423T
44LT-21a/443T

LLLT-21b/113T

PPL-22a/PP3T
LLL-22a/LL3T
11L-22a/113T
12L-22a/123T
41L-22a/413T
42L-22a/423T
44L-22a/443T

LLL-22b/113T

113-22c/AAA
114-22c/AAA
123-22c/AAA
124-22c/AAA
413-22c/AAA
414-22c/AAA
423-22c/AAA
424-22c/AAA

PP3-22d/PPA
PP4-22d/PPA
LL3-22d/LLA
LL4-22d/LLA
443-22d/LLA

PP3T-23/NONE
PP3-23/NONE
PP4T-23/NONE
PP4-23/NONE
LLLT-23/NONE
LL3T-23/NONE
LL3-23/NONE
LL4T-23/NONE
LL4-23/NONE
11LT-23/NONE
113T-23/NONE
113-23/NONE
114T-23/NONE
114-23/NONE
12LT-23/NONE
123T-23/NONE
123-23/NONE
124T-23/NONE
124-23/NONE
41LT-23/NONE
413T-23/NONE
413-23/NONE
414T-23/NONE
414-23/NONE
42LT-23/NONE
423T-23/NONE
423-23/NONE
424T-23/NONE
424-23/NONE
44LT-23/NONE
443T-23/NONE
443-23/NONE
444T-23/NONE
RRRT-23/NONE
CCC-23/NONE

PP3T-24/NONE
PP3-24/NONE
LL3T-24/NONE
LL3-24/NONE
113T-24/NONE
113-24/NONE
123T-24/NONE
123-24/NONE
413T-24/NONE
413-24/NONE
423T-24/NONE
423-24/NONE
443T-24/NONE
443-24/NONE

PP3T-25a/PP4T
PP3-25a/PP4
LL3T-25a/LL4T
LL3-25a/LL4
113T-25a/114T
113-25a/114
123T-25a/124T
123-25a/124
413T-25a/414T
413-25a/414
423T-25a/424T
423-25a/424

443T-25b/444T
443-25b/444T

11LT-26/41LT
11L-26/41L
113T-26/413T
113-26/413
114T-26/414T
114-26/414
12LT-26/42LT
12L-26/42L
123T-26/423T
123-26/423
124T-26/424T
124-26/424

41LT-27/NONE
41L-27/NONE
413T-27/NONE
413-27/NONE
414T-27/NONE
414-27/NONE
42LT-27/NONE
42L-27/NONE
423T-27/NONE
423-27/NONE
424T-27/NONE
424-27/NONE

42LT-28a/44LT
42L-28a/44L
423T-28a/443T
423-28a/443

424T-28b/444T
424-28b/444T

AAA-31/LLA
LLLT-31/LLL
11LT-31/11L
12LT-31/12L
41LT-31/41L
42LT-31/42L
44LT-31/44L
444T-31/444
RRRT-31/RRR
CCC-31/NNN

PP3T-32/PP3
PP4T-32/PP4
LL3T-32/LL3
LL4T-32/LL4
113T-32/113
114T-32/114
123T-32/123
124T-32/124
413T-32/413
414T-32/414
423T-32/423
424T-32/424
443T-32/443

PPP-33/NNN
PPL-33/LLL
PP3T-33/LL3T
PP3-33/LL3
PP4T-33/LL4T
PP4-33/LL4
PPA-33/LLA